On November 23 and 24, 2021, a symposium entitled: "The legacy of Pierre-Gilles de Gennes: a source of inspiration for the future" was organized in Paris. Thirty years after his Nobel Prize, and 14 years after his death at the age of 74, one of his collaborators who spoke at this conference, presents below his personal views and recollections.

Pierre-Gilles de Gennes: The man and his scientific heritage

by David Andelman

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Pierre Gilles de Gennes, called PGG by his close friends, continues to be a source of inspiration even for the younger generation of scientists who did not know him personally. Who was this extremely atypical and original French scientist? And why have his scientific approach and contributions left such an enormous impact on science for over 60 years? I will try to present a short and rather personal account below.

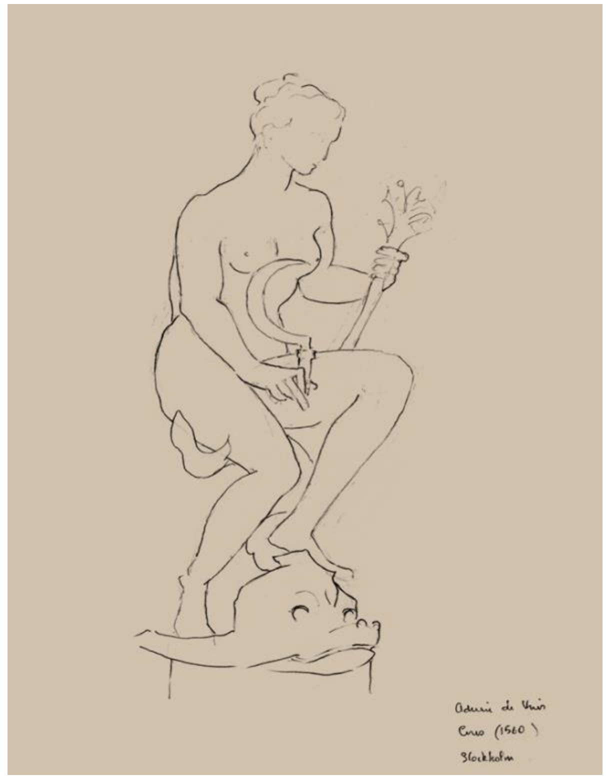
His life

De Gennes was born in Paris in 1932 and was educated at home by his mother until he was twelve years old. After two years of preparatory classes at Lycée St-Louis, he joined École Normale Supérieure in Paris. He then completed his PhD at the Saclay research center of the French Atomic Energy Commission (CEA) in 1957 on neutron scattering and magnetism and spent three years in the military service in the Sahara working on nuclear testing. After a postdoctoral stay at the University of California at Berkeley, he joined the University of Paris at Orsay in 1961 and created the *Orsay group on superconductivity* and then the *Orsay group on liquid crystals*. In 1971, he became a professor of Condensed Matter Physics at Collège de France (Paris) and, at the same time, Director of ESPCI (School of Industrial Physics and Chemistry of the city of Paris), where he remained until his retirement in 2002. After retirement, he continued to work on cell adhesion and neuroscience at the Curie Institute in Paris. He passed away in 2007.

How did de Gennes work?

It is clear to all those who knew de Gennes that he was extraordinary in terms of his vision and depth of thought. He was extremely productive as a scientist and recognized with numerous prizes, awards, honorary doctorates, and was elected as a member of scientific academies around the world. A partial list of his honors includes the Matteucci Medal (Italy), Harvey Prize (Israel), Lorentz Medal (The Netherlands), Gold Medal of the French CNRS, Ampère Prize (France), Wolf Prize (1990), and the Nobel Prize (1991). The Nobel Prize was awarded to him "*for discovering that methods developed for studying order phenomena in simple systems can be generalized to more complex forms of matter, in particular to liquid crystals and polymers*". The

Nobel Prize allowed him to share his knowledge with the general public and high-school students by visiting more than two hundred high schools and giving lectures that were followed by a lively and passionate discussion with the audience. One of de Gennes' characteristics was his taste for sharing and transmitting ideas and knowledge. De Gennes, who was an excellent draughtsman, conveyed his scientific ideas through sketches of great simplicity, which nevertheless conveyed their deep meaning. Compared to "Big Science", he valued table-top experiments, and above all, he listened attentively to those who came to hear him.



De Gennes's work

During his long career, de Gennes made fundamental contributions to many areas of complex and disordered condensed matter physics and, later on, to chemical and biological systems.

His early contributions were in magnetism where he proposed how neutron scattering is related to magnetic phase transitions and "double exchange" in rare-earth materials -- a special type of magnetic materials. In the 1960s, the "*Orsay group on superconductivity*" under his leadership combined the microscopic theory of the three Americans, Bardeen, Cooper, and Schrieffer (the BCS theory) who received the Nobel Prize in 1972, with the phenomenological approach of the famous Russian physicist, Lev Davidovich Landau, to treat complicated geometries, by setting up an experimental team of four researchers whom he later called "his four musketeers". Interesting predictions and experimental results on the behavior of superconductors at surfaces and interfaces were obtained. His book, which appeared in 1966, entitled "*Superconductivity of metals and alloys*" remains a valued reference even today.

Work on liquid crystals began in the late 1960s at Orsay. Some of his results, like the transition between the nematic and smectic phases of liquid crystals, relied on the analogy of the phase transition between metals and superconductors. Here, de Gennes began to use his famous scaling analysis of physical phenomena, which emphasized universal behavior rather than specific details. De Gennes' approach was then applied to liquids crystals in a multitude of confined geometries, phase transitions, defects, and in presence of external forces. His book "*The Physics of Liquid Crystals*", which was published in 1974 (second edition with J. Prost in 1994) summarizes his views on these systems.

Another key shift in his interests occurred in the early 1970s when de Gennes began to study long, flexible molecules ("entangled spaghetti") called polymers, which are the building blocks of plastics as well as proteins and hydrocarbons of living systems. His landmark work in 1972 highlights the exact correspondence of a physical polymer (self-avoiding random walk) with a system of magnetic spins in a completely imaginary limit called the "*n=0 theorem*" (for systems with a limiting zero dimension!). This work was inspired by the approach of K. Wilson's renormalization group for phase transitions and critical phenomena (Nobel Prize 1982). His 1979 book on scaling effects "*Scaling concepts in polymer physics*" summarized his views on single-chain behavior as well as polymers in different solutions, the invention of polymer "*blobs*" and self-similarity (fractal-like behavior) of chains at surfaces. The puzzling dynamics of entangled polymer chains were modeled by a "*reptation in a tube*" model. Here, de Gennes' work had a strong overlap with a famous British scientist, Sir Sam Edwards. They never worked together but had great respect for one another and kept in close contact.

De Gennes has made fundamental contributions to other areas of disordered and complex materials. His article on "*Wetting: static and dynamic*" from 1984 is still widely quoted today. This article was followed by the book "*Capillarity and wetting phenomena*" (with F. Brochard-Wyart and D. Quéré). De Gennes also worked on microemulsions (stable mixtures of oil, water, and surfactants), on bio-cellular adhesion, and, later in life, on neurobiology.

Conclusions

In an attempt to explain de Gennes's unique scientific approach, here are some of his quotes from various occasions [for more details, see the book: "*L'extraordinaire Pierre Gilles de Gennes*" (F. Brochard, M. Veyssié and D. Quéré) published by O. Jacob in French].

- "A scientist's real point of honor is not always to be right. It is to dare to propose new ideas and then to check them".
- About thermonuclear fusion, he wrote: "*We say that we will put the Sun in a box. The idea is pretty. The problem is that we don't know how to make the box*".
- At the Nobel Prize banquet in 1991, he publicly declared: "*It's the first and probably the last time in my life that I'm going to have dinner with queens and princesses. I'm worried. I suspect that with the midnight chimes, I will be turned into a pumpkin*…"
- And in the Imaginary Library of Collège de France in Paris, he wrote: "*The melancholy of our sciences is the difficulty of transmitting. Three lines from Picasso and a phrase from Vinteuil Sonata (Marcel Proust) are enough to move us, but it takes many years to feel the beauty of a new idea in physics"*.

When we try to understand why de Gennes was so influential, we are faced with a paradox. His scientific style was unique. It was extremely appealing to others but impossible to replicate. It seems that his greatest driving force was his immense curiosity for new phenomena and experimental results. His powerful technical skills were often masked by intuitive physical reasoning. He mastered many areas of physics and freely used abstract analogies between what appeared to be very different systems. For example, he used the analogy between superconductivity and liquid crystals to explain the nematic to smectic phase transition, or the analogy between a polymer chain and a magnetic spin system. These analogies (as indicated by his Nobel Prize citation) allowed him to give birth to a new vision of unexplored and complex physical systems such as liquid crystals, polymers, colloids, granular matter, and wetting and interfacial phenomena.

In his choice of phenomena to study, de Gennes has always emphasized a holistic approach, where new understanding is based on the synergy between theory and experiments, between fundamental and applied research, and on the advantages of exchanging ideas and concepts between different scientific disciplines: physics, chemistry, biology, and engineering. On a more personal level, his charisma, enthusiasm, and perseverance as well as the respect he showed towards other established scientists and even students were appreciated by many and contributed to his leadership and legacy.

I will end on a more personal note. After completing my doctorate at MIT in 1984, I was a post-doctoral fellow in de Gennes' laboratory at Collège de France for two years. These two years had a significant impact on my scientific career. The atmosphere in the lab was very different from what I was used to at MIT. Strongly inspired by his style, there were many collaborations with different groups. I have witnessed his incredible way of solving complex problems or understanding new experimental results. He would deconstruct the problem, and then reconstruct it from its essential elements, ignoring the unimportant details.

When Pierre-Gilles de Gennes died in 2007, numerous obituaries and articles about him and his legacy appeared in the press. I want to quote an article by an Indian physicist, Anita Mehta, published in The Hindu on 31/5/2007: "Pierre-Gilles de Gennes, the physicist who won the Nobel Prize, practiced science as many practice art".

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